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TIMBER-FISH-WILDLIFE PROJECT

THE EFFECT OF ELEVATED HOLDING TEMPERATURES ON ADULT SPRING CHINOOK SALMON REPRODUTIVE SUCCESS

INTERIM FINAL REPORT

THE EFFECT OF ELEVATED HOLDING TEMPERATURES ON ADULT SPRING CHINOOK SALMON REPRODUCTIVE SUCCESS

by

Cara H. Berman
Thomas P. Quinn

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Center For Streamside Studies/Fisheries Research Institute
University of Washington
Seattle, Washington 98195

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I: EXECUTIVE SUMMARY

Information regarding the effects of elevated temperature on the behavior and reproductive success of spring chinook salmon is lacking. Adult spring chinook salmon enter freshwater in spring, and thus are susceptible to temperature extremes prior to spawning. While daily and seasonal fluctuations in temperature are natural characteristics of rivers, logging practices can exaggerate these fluctuations exposing mature spring chinook salmon to potentially harmful temperatures. The acute effects of elevated temperature on fishes have been well documented. However, information on the effect of long-term exposure of salmonids to sub-lethal temperatures is scarce. Recent findings suggest that alterations to tissue and blood chemistry and egg viability and survival may occur in association with prolonged exposure to elevated temperatures.

A two phase study was designed to investigate the possible link between timber harvesting practices and spring chinook salmon reproductive success. The objective of the study is three-fold: a) to characterize the thermal regimes historically tolerated by spring chinook salmon and to model the likely effects of forest practices on their success, b) to determine if temperatures experienced by adult spring chinook salmon prior to spawning influence reproductive success, and c) to determine if adult spring chinook salmon are capable of behaviorally regulating their internal temperature. Phase I, a pilot study to determine if temperatures experienced by adult spring chinook salmon prior to spawning influence their reproductive success, was completed during fiscal year 1988 (July 1, 1988 - June 30, 1989). The pilot study was conducted to assess potential problems in the Phase II adult holding study experimental design and methodology. Study site selection for the Phase II holding study and the radio telemetry study was also completed during this period. A literature and historical study to characterize the thermal regimes historically tolerated by spring chinook salmon will be ongoing throughout the study.

The pilot study was conducted at the Kalama Fails State Hatchery and the Weyerhaeuser Company's Kalama Springs facility. Twenty adult spring chinook salmon were selected from the Kalama Falls State Hatchery and were divided equally into a warm (10.0- 16.70 C) temperature treatment group maintained at: the hatchery and a cool (4.4 - 6.0° C) temperature treatment group maintained at the springs. Upon reaching sexual maturity, fish from both temperature treatment groups were spawned. Unfertilized eggs and milt were transported to the University of Washington where the eggs were fertilized and incubated. The incubation unit was maintained at constant temperature to ensure the expression of only pre-spawning thermal effects. Rate of egg development, developmental stage at egg mortality, egg weight and volume, occurrence of developmental abnormalities, and hatching rate were recorded.

Interpretation of results from the pilot study was complicated by the presence of several confounding variables. Therefore, statistical analysis of the data was not deemed appropriate. However, qualitative analysis is provided. The pilot study provided useful information regarding the experimental design and methodology to be used in the Phase II adult holding study. Study site selection was determined to be the primary factor affecting the success of the holding study. Priest Rapids State Hatchery was chosen as the study site because it provides access to water of both elevated and non-elevated temperatures that can be mixed to provide similar water quality in each treatment group. In addition, the Yakima River was chosen as the radio telemetry study site. Due to adjustments made to the experimental design during Phase I, the adult holding study should provide meaningful results that when combined with historical and tracking data and the temperature models will allow one to predict whether sites will experience sufficient post-logging warming to endanger the reproductive success of spring chinook salmon.

II: INTRODUCTION

A literature search has revealed a paucity of information regarding the effects of elevated temperature on the behavior and reproductive success of adult salmon (Berman, 1988). Specifically, information regarding temperature preference of seasonal runs of chinook salmon is inconclusive or lacking. Adult spring chinook salmon enter freshwater in spring (February-June), and are susceptible to possible elevated water temperatures during summer prior to spawning. Tribes, management agencies, private industry, and educational groups involved with fisheries and forestry issues in Washington have expressed particular concern regarding the issue of elevated stream temperature and its effect on spring chinook salmon reproductive success (P. Bisson, Weyerhaeuser; K. Sullivan, Weyerhaeuser; L. Wasserman, Yakima Indian Tribe; D. Schuett-Hames, Lummi Indian Tribe; B. Ready, Hatchery Manager, Kalama State Fish Hatchery; personal communication).

The Center for Streamside Studies (CSS) was "formed to improve our understanding of interactions between natural and managed terrestrial and aquatic ecosystems" (CSS Research Plan 1988). The investigation of temperature effects on spring chinook salmon behavior and reproductive success will address one of the more controversial areas regarding fishery/forestry interactions thermal effects - and will include one of the least studied and most threatened salmonid races in Washington, the spring chinook salmon. Sub-lethal effects of altered thermal regimes have seldom been documented for salmonid populations in logged watersheds (Holtby 1988). However, indirect and sub-lethal effects on fish populations due to temperature changes resulting from logging and other habitat alterations are perhaps more the rule than the exception (Holtby 1988). Holtby (1988) reported that habitat perturbations, such as temperature elevation, can effect more than one life history stage, persist throughout the life cycle, and persist into the marine phase.

While daily and seasonal fluctuations in temperature are natural characteristics of rivers, logging practices can potentially exaggerate these fluctuations by reducing shading, decreasing water depth (by siltation), and by raising local air temperatures in clearcut areas (Adams and Sullivan 1987; Holtby 1988). Increased stream temperatures have been observed coincident with the beginning of intensive logging. These increases were apparent in all months of the year, but were particularly striking during summer (May~

September) (Moring an(:[Lantz I975; Hartman 1982; Holtby 1988). Additionally, estimates of historical temperature data for Carnation Creek provided evidence that in most months temperatures were either outside the historical range or unusually warm (Holtby 1988). Temperatures do not return to pre-logging levels until stream banks become revegetated (Holtby 1988). Thus, elevated stream temperatures may persist over many years.

Natural or anthropogenic fluctuations in water temperature can induce a wide array of behavioral and physiological responses in salmonids. Numerous authors have noted the importance of temperature on the life history traits of Pacific salmon (Olson and Foster 1955; Combs 1965; Olson and Nakatani 1969; Moring and Lantz 1975; Bouck et al. 1975; Dong 1981; Heming 1982; Hartman 1982; Smith et al. 1983; Kamler and Kato 1983; Garling and Masterson 1985; Neitzel and Becker 1985; Beacham and Murray 1986; Beacham and Murray 1986; Brannon 1987; Tang et al. 1987; Holtby 1988; Cunjak 1988; Murray and McPhail i988; Linley 1988). As poikilotherms, salmonids are strongly influenced by the thermal regime of their habitat, and the extent of that influence has been documented in the life cycles of different species (Brannon 1987). Mechanisms have evolved to synchronize the timing of salmonid life history events with their physical environment, and are believed to have been a major factor in development of specific stocks (Brannon 1987). Several authors have linked variation in temperature requirements to genetic differences imposed by differences in environmental temperature regimes (Brannon 1987; Tang et al. 1987; Murray and McPhail 1988). Temperature can affect the time of migration of adults and the time of spawning. Spawning, in turn, influences the incubation temperature regime, which influences survival rates, development rates, and growth of embryos and alevins.

Previous research on temperature sensitivity of fishes emphasized lethal limits and temperature preference. Current concerns have centered on the effect of long-term exposure of salmonids to sub-lethal temperatures. Holtby (1988) reported[that virtually all effects of an altered thermal regime on populations are associated with relatively small temperature increases over short periods in late winter and spring. Effects of elevated water temperature could be even greater where water temperatures are naturally high. Recent findings suggest that alterations to tissue and blood chemistry may occur in association with prolonged exposure to elevated temperatures (Bouck et el. 1975; Strange 1980; Thomas et al. 1986). These alterations may lead to impaired functioning of the fish and thus decreased viability. Feeding, resistance to disease, successful reproduction, and sufficient activity to permit existence in the face of competition and predation are all necessary for the survival of the organism and population. Inability to maintain any of these activities at moderately extreme temperatures may be as decisive to continued survival as more extreme temperatures to immediate survival.

Although there is growing concern regarding sub-lethal thermal effects on salmonids, little data exist on the effects of elevated temperatures on adults (Berman 1988). Studies have investigated temperature sensitivity of salmonid eggs and alevins (Olson and Foster 1955; Combs 1965; Olson and Nakatani 1969; Ringler and Hail

1975; Dong 1981; Heming 1982; Kamler and Kato 1983; Gaffing and Masterson 1985; Neitzel and Becker 1985; Beacharn and Murray 1986; Beacham and Murray 1986; Brannon 1987; Tang et al. 1987; Murray and McPhail 1988) but these experiments only examined effects from fertilization through emergence of the fry. Pre-spawning effects were not considered. However, Smith et al. (1983) reported that elevated temperatures experienced by mature female cutthroat trout affected the subsequent viability and survival of the eggs. Bouck et al. (1975) reported decreased body length and weight, increased ventilation activity, increased liver size, decreased fat reserves, increased atrophy of the gastrointestinal tract, decreased gonad size and weight, and decreased egg weight of mature sockeye salmon exposed to sub-lethal temperatures. Moreover, the manager of the Kalama State Fish Hatchery (B. Ready, personal communication) has reported egg mortalities of 50% or more from adults held at temperatures from 14.4° C to 19.4° C.

During fiscal year 1988 (July 1, 1988 - June 30, 1989), the first phase of a two phase study investigating the possible link between timber harvesting practices and spring chinook salmon reproductive success was completed. A pilot study at the Kalama Falls State Hatchery and the Weyerhaeuser Company’s Kalama Springs facility was conducted to assess potential problems in the adult holding study experimental design and methodology designed to determine if temperatures experienced by adult spring chinook salmon prior to spawning influence reproductive success. In preparation for a major adult holding study and radio telemetry study to be conducted during Phase II of the study, site locations were assessed and experimental designs were construcLed. A literature and historical survey to characterize the thermal regimes historically tolerated by spring chinook salmon will be ongoing throughout the entirety of the study. In accordance with adaptive management theory, information obtained from the pilot study and the final study can be integrated with results from other TFW projects and used for ecosystem scale analysis and management.

The adult holding study will provide data regarding the alteration of early life history parameters (i.e. egg size, egg weight, and rate of development) due to elevated water temperatures. These parameters have been identified as possible mechanisms by which fry emergence timing is regulated (Brannon 1987; Murray and Mcphail 1988; Linley 1988). Thus, alteration of these events through sub-lethal temperature effects may lead to smaller progeny and/or altered migration timing. Both smolt size and time of migration have been associated with variations in marine survival (Bilton et al. 1980; Bilton et al. 1984; Tipping 1986). The size of fry at emergence is fundamental to survival of salmonids due to effects on swimming performance, vulnerability to predators., and subsequent growth (Bilton etal. 1980; Bilton etal. 1984; Holtby 1988; Murray and McPhail 1988). Furthermore, energy stores which are rapidly depleted between late summer and early winter could decrease survival of unusually small fry (Cunjak and Power 1987; Cunjak 1988). If mechanisms controlling temporal patterns in salmonid behavior exist to achieve synchronized emergence with environmental events in their natural habitat, alterations to this temporal sequence through alteration of egg size, egg weight or rate of development could have severe effects on spring chinook salmon populations.

III: METHODS

The relationship between spring chinook salmon reproductive success and logging related temperature elevations were addressed in a two-pronged approach involving analysis of historical records and a controlled adult holding experiment. First, records on the spatial distribution and timing of migration and spawning of spring chinook salmon in Washington, both extant and extinct, were examined (Wahle and Pearson 1987; Army Corps of Engineers 1986; Wahle and Smith, 1979). During Phase II, temperature models to be approved by the TFW Ambient Monitoring Steering Committee and stream records will be used to estimate temperature regimes and effects of logging practices on rivers in an effort to characterize the thermal regimes historically tolerated by spring chinook salmon and to model the likely effects of forest practices on their success. Experimental results will later be integrated with the historical spawning and migration records and temperature modeling to predict whether spring chinook salmon experience sufficient post-logging warming to endanger their reproductive success.

The second approach was an experimental study to address the hypothesis that temperatures experienced by adult spring chinook salmon prior to spawning influence reproductive success by altering the number, size, and/or weight of eggs deposited by the female, and the subsequent survival of offspring to emergence. The effect of temperature on egg production and subsequent egg development through hatching was observed. Phase I of this study was conducted as a pilot study to produce an experimental design and methodology and to explore study site options for Phase II of the study. The pilot study was conducted at the Kalama Falls State Hatchery and the Weyerhaeuser Company's Kalama Springs facility. Those fish maintained at the Kalama Falls State Hatchery experienced summer temperatures of 10.0 16.7° C while those fish maintained at the Kalama Spring experienced temperatures of 4.4 6.0° C. The study site was chosen as water of both high and low water temperatures were present, high hatchery egg mortality rates had been reported, and upstream areas had experienced timber harvesting. Flexibility in water supply and water temperature was of major importance in site determination.

On August 30, 1988 20 adult female spring chinook salmon were selected for study from the Kalama Falls State Hatchery sorting pond. These fish had entered the hatchery between August 1 and August 3, 1988 and subsequently had not experienced chemical treatments (erythromycin, formalin) administered to other fish. The fish were divided equally into a warm water group, maintained at the Kalama Falls State Hatchery, and a cool water group, maintained at the Weyerhaeuser Company's Kalama Springs facility. The 20 female spring chinook salmon experienced identical conditions during handling and transportation prior to initiation of temperature treatments. Individuals within the sorting pond were placed in a plastic tub containing 38 gms of MS-222 and were removed from the bath at first sign of anesthetic effect. Fish were immediately injected with 0.5 cc per 4.5 kg erythromycin and injected with two T-tags at the base of the dorsal fin. Treatment fish were then placed within a 3,800 liter truck tank equipped with aeration pumps. Water within the tank was treated with 22.5 kg of salt and 56.2 kg of crushed ice. During transport to Katama Springs water temperature within the tanker rose from 11.7° C to 14.4° C. The temperature of Kalama Springs was 8.9° C~ During replicate transport treatment for the hatchery fish, water temperature within the tanker rose from 16.70 C to 17.2° C. Hatchery pond temperature was 14.4° C.

Hatchery and Kalama Springs fish remained in the tank for one hour and 17 minutes (load time = 15 minutes, travel time = 47 minutes, unload time = 15 minutes). Upon completion of transport, 76 gms of MS-222 were added to the tank. Individual fish were removed from the tank and placed in one of two 133 liter plastic garbage cans containing approximately 38 liters of spring or hatchery water. Kalama Springs fish were transported to a net enclosure consisting of :four panels measuring 6.1 meters in length and 2.4 meters in depth with a 6.1 meter square cover net. Side panel netting was knotless polyester of 0.04 meter mesh with .45 kg per 0.30 meter lead weights. The cover net was knotless polyester of 0.06 meter mesh. Twenty sandbags were used to further secure the side panels to the substrate. A black visquine tarp covering a quarter of the enclosure provided shade. Hatchery fish were placed in the hatchery pond with other spring chinook salmon. The pond was treated with a formalin drip of *5.0* cc per 380 liters inflow. Kalama Springs fish were not treated with formalin. Data regarding daily temperature, dissolved oxygen, and pH were collected at the Kalama

Fails State Hatchery and Kalama Springs sites. All mortalities were diagnosed for disease presence at the Kalama Fails State Hatchery. A field assistant resided at Kalama Springs full-time to maintain equipment and to patrol the study site.

Upon reaching sexual maturity (September), fish from both temperature treatment groups were spawned. The size and quality of the eggs expelled per adult female i.e. broken or opaque eggs were recorded. Ovarian fluid samples were transported to the Washington Department of Fisheries to determine IHN contamination. Egg samples (500 eggs per female) and milt were placed in separate plastic sampling bags and were transported to the University of Washington in a cooler containing "blue ice". Travel time to the university was approximately 4 hrs. Toweling was placed between the sample bags and ice to prevent damage to gametes. At the university, eggs were fertilized with milt taken from a pooled sample of hatchery males on the day of each egg-take and water hardened in Argentyne. Fertilized eggs were placed into individual egg cups and incubated through hatching within a trough fed by dechlorinated, chilled city water. The trough contained a pump, that when activated by a float switch, removed a portion of the water within the incubation unit once every 7 mins. Malachite green treatments were conducted every three days from September 7, 1988 to October 4, 1988 and every four days until the eyed stage. Water temperature was maintained at approximately 9.0° C. Dissolved oxygen was maintained at 7 mg/ml oxygen to ensure identical egg development conditions. Egg mortalities were recorded and placed in Stockard's Solution (40 ml acetic acid, 50 ml formaldehyde, 60 ml glycerin, and 850 ml distilled water) to determine developmental stage at mortality (Fleming and Ng 1987). Records were maintained regarding the rate of egg development; developmental stage at egg mortality; egg weight and volume; occurrence of developmental abnormality; and hatching rate. In addition, egg survival rates at the Kalama Falls State Hatchery were compared with survival rates of past years and with survival rates of Kalama River eggs incubated at the University of Washington.

IV: RESULTS AND DISCUSSION:

Phase I objectives included the design and completion of a pilot study to produce an experimental design and methodology for the evaluation of temperature effects on adult spring chinook salmon reproductive success~ ongoing literature and historical studies, and selection of tracking and major adult study sites. Interpretation of results from the pilot study were complicated by the presence of several confounding variables. Thus, when reviewing data derived from the pilot study it is imperative that differences between the treatment groups not be attributed solely to temperature.

Fish within the two treatment groups not only experienced differences in temperature, but they also experienced differences in water quality, pathogen exposure, holding apparatus, and handling and crowding stress. Experimental fish maintained at the hatchery were held in the primary holding pond containing hatchery fish. Thus, they received formalin treatments to reduce fungal infection. Fish maintained at Kalama Springs were not treated with formalin or malachite green and fungal infection was a serious problem. Only four of the ten original Kalama Springs fish survived to spawning. Mortalities at the springs were heavily infected with fungus both on the body and the gills. All females utilized in the experiment tested IHN negative.

The ten females spawned from the hatchery were not the original females that experienced pre-treatment handling and transport conditions. On the day of first egg-take there were no tagged fish remaining within the hatchery pond. Apparently, the T-tags were not effective in crowded hatchery conditions. Therefore, ten ripe females were randomly selected from the hatchery pond and spawned. Thus, due to confounding variables and the inability to differentiate between the experimental and non-experimental fish maintained at the hatchery, statistical analysis of the data was not deemed appropriate. However, qualitative analysis is provided and a summary of the data appears in the appendix. The revised work study plan dated March 3, 1989 alleviates the effect of confounding variables encounterd during the pilot study. It must be remembered that the primary objective of the pilot study was to provide an experimental design to be used during Phase II of the study.

Eggs from both the warm (10.0 - 16.7° C) and cool (4.4 - 6.0° C) water treatment groups were incubated at the university. Egg lots #1-10 were from females maintained at the hatchery whereas egg lots #11-14 were from females maintained at the springs. Both groups showed similar mortality rates through hatch (Appendix liD. However, egg lot #11 exhibited almost: complete mortality. The possible cause for the extreme mortality exhibited by this female is unclear, However, eggs from lot #11 incubated at the hatchery also exhibited a rather high mortality rate (40.3%). Mortality data to the eyed stage was also recorded for temperature treatment eggs incubated at the hatchery (Appendix IV). Lots #1-10 had an average mortality rate of 8%, while lots #11-14 had an average mortality rate of 36%. Rate of development for all egg lots was similar except during hatching (Appendix VI). Time from first hatch to complete hatch could not be compared due to placement effects within the incubation unit. Eggs were smaller from lots #11-14 (Appendix VII). However, adult length and weight measurements were not recorded, and therefore it is difficult to draw conclusions regarding egg size.

Temperature data compiled by the Kalama Falls State Hatchery for 1985 1988 show that the average maximum and the monthly high temperatures were cooler in 1988 than the other years (Appendix I). In addition, low night-time temperatures may have offset daytime highs, thereby mitigating temperture effects. Kalama Springs fish experienced temperatures of 4.4 6.0° C. These temperatures are significantly lower than the Kalama Fails State Hatchery temperatures and they showed no significant day/night fluctuations. Egg mortality at the Kalama Falls State Hatchery varied from a low of 3.85% in 1985 to a high of 20% in 1987. The 1988 egg mortality was 11.4% (Appendix II). Egg mortalities do not correspond directly to temperature extremes. However, it is difficult to determine from the records whether mortalities were related to temperature or other variables such as disease outbreak or sediment load that may affect egg survival.

The pilot study provided useful information as to experimental design and methodology to be used in the formulation and implementation of the Phase II adult holding study. Study site selection was determined to be the primary factor effecting the success of the adult holding study. Flexibility in water supply and temperature were of the utmost importance. To produce meaningful conclusions regarding temperature effects on adult spring chinook salmon reproductive success, water quality in the two temperature treatment groups must be identical. In addition, treatment groups must be isolated from non-experimental fish such that formalin treatments can be provided to prevent mortality due to fungal infection. Division of experimental fish from hatchery fish will also reduce the exposure of experimental fish to non-experimental treatments such as large-scale hatchery operations may warrant. Priest Rapids State Hatchery was chosen as the site of the major adult holding study as it provides access to water of both elevated and non-elevated temperatures while isolating both the experimental fish and effluent from hatchery rearing and adult holding areas. The two water sources are derived from cooler spring and warmer river water and can be mixed to provide similar water quality in both treatment groups. The spring chinook salmon will be divided into temperature treatment groups each consisting of ten males and ten females. These two groups will be subdivided and maintained in eight separate circular tanks treated with formalin. During the month of June 1989 the eight circular tanks will receive well water maintained at approximately 12° C. After that date water entering the circular tanks will be a mixture of well and river water maintained at approximately 19° C (elevated temperature regime) and approximately 12° C (non-elevated temperature regime).

Effluent from the eight circular tanks will be treated with chlorine (2 ppm). Fish will experience natural photoperiod and temperature cycles. The eight circular tanks provide replication of the temperature treatment groups.

Due to the absence of spring chinook salmon populations at Priest Rapids State Hatchery, Yakima River adult spring chinook salmon will be utilized. Yakima River spring chinook salmon were chosen for use in the study as they are from a wild brood stock, they may be easily obtained at Roza Dam, and they are the same stock to be used in the radio telemetry study. Fertilized eggs will again be incubated at the University of Washington. However, eggs will be fertilized with milt from males of the same temperature treatment group. A sub-set of eggs will be placed into individual egg cups and incubated within a trough fed by dechlorinated, chilled city water. Egg cup position will be randomized to reduce placement effects observed during the pilot study. Other details of the holding study will remain as described in the pilot study.

Records on the spatial distribution and timing of migration and spawning of spring chinook salmon in Washington are being compiled. Once a temperature model is approved by the TFW Ambient Monitoring Committee, the temperature model and stream records will be used to estimate temperature regimes and effects of logging practices on those rivers with spring chinook salmon populations in an effort to characterize the thermal regimes historically tolerated and model the likely effects of forest practices on their success. Analysis of historical records is ongoing and will be compiled for the Annual Report to be completed June 30, 1990.

The radio telemetry study site was also determined. The Yakima River was selected, based on the following criteria: natural population of spring chinook salmon, ease of access to salmon for transmitter insertion, low fishing pressure, upstream timber harvesting, elevated summer water temperatures, and availability of springs and tributaries of differing temperatures from mainstem holding areas. Upon entering the holding facility at Roza Dam, temperature sensitive-radio transmitters will be inserted into the stomachs of 20 adult spring chinook salmon. All transmitters will be calibrated prior to insertion. Due to the fish capture and holding facilities at Roza Dam, undue stress to the fish will be minimized, and greater accuracy in transmitter placement and reliability of data sets will be achieved. Individual fish will be captured at the Roza Dam fish trap and anesthetized with MS-222. These fish will not be handled until they are anesthetized. The transmitter will be inserted into the stomach and the fish will be placed into a live box for recovery. Aeration will be provided and water temperatures monitored in the live box. Upon recovery from the MS -222 treatment, fish will be placed in a net pen for 24. hours to ensure recovery of the fish and functioning of the transmitter. The trailing antenna will be secured to the roof of the fish's mouth to prevent regurgitation. After insertion of the transmitter, individual fish will be monitored for internal body temperature and movement within the river system for a period of at least three months. Fish will be observed from shore and from boat. In addition to the transmitters, snorkeling may be conducted to obtain temperature data and habitat information. During the summer continuous temperature recordings will be made in the river and adjacent seeps and streams. Approximately eight Omnidata electronic temperature recorders (data pods) will be placed within the Yakima River to record river temperatures. A temperature profile of the holding area will be assembled. Thus, the study will document the extent to which internal temperature is behaviorally regulated by selection of temperature-related holding sites.

V: SUMMARY AND CONCLUSIONS

The pilot study was conducted to assess the effectiveness of the experimental design and methodology to be used in the Phase II adult holding study. Although statistical analysis of the data was precluded due to confounding variables, information gained from the pilot study was invaluable. The experimental design and methodology of the Phase II adult holding study were modified to incorporate the findings of the pilot study.

Although data generated during the pilot study is difficult to interpret, it does provide some insight into the complexity of environmental factors that control egg viability. Survival rate of eggs incubated at the university did not differ greatly between females maintained at the Kalama Falls State Hatchery and females maintained at Kalama Springs. However, survival rate did vary between warm water and cool water treatment groups incubated at the hatchery. This could be due to differences in transport time and/or fertilization and incubation methods or in the length of time mortalities were recorded. The hatchery only recorded mortalities through the eyed stage whereas eggs incubated at the university were monitored through hatch. Temperatures at the hatchery were lower than in past years and thus could have contributed to the high survival rate of the eggs. The use of formalin on fish in the hatchery and not on fish in the spring probably had the greatest impact on egg viability. Although fish maintained at the spring were in cool filtered water with ample space, fungal infection was a serious problem. During the Phase II holding study all experimental fish will be maintained in circular tanks where they will be treated with formalin. This should control fungal outbreaks, while providing identical holding apparatus and exposure to similar handling and crowding stress. In addition, there will be no need to tag fish for later identification. The ability to mix water sources will allow fish within each circular tank to experience similar water quality conditions and pathogen loads. The use of eight replicate treatment tanks will allow differentiation between treatment effects and inherent variability between fish and tanks. Thus, Phase II results will complement data obtained from the radio telemetry study and the historical and literature review. Historical, experimental, and tracking data will be combined with the Ambient Monitoring Committee temperature models to predict whether any spring chinook salmon sites would experience sufficient post~logging warming to endanger the reproductive success of the salmon. Results of the study will provide valuable information for the development of fisheries management and timber harvesting practices.

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VII: APPENDIX

I. Kalama State Hatchery Temperature Data: Average Maximum and Minimum Temperature and Monthly High and Low

YEAR: 1985

MONTH	MAXIMUM	MINIMUM	Hi	Lo
April	7.6° C	6.2° C	8.9° C	3.3° C
(4/1-4/7, 4/18-4/20 data absent)				
May	8.9° C	7.9° C	12.8° C	6.7° C
(5/14-5/19, 5/24-5/25, 5/27-5/31 data absent)				
June	12.9° C	11.6° C	15.0° C	8.9° C
(6/1-6/8, 6/23-6/28 data absent)				
July	17.4° C	13.6° C	19.4° C	10.6° C
(7/4-7/21, 7/31 data absent)				
August	14.6° C	11.9° C	15.0° C	11.7° C
(8/1-8/27 data absent)				
September	12.3° C	11.3° C	13.9° C	9.4° C
(9/15, 9/17-9/21, 9/24-9/30 data absent)				
1986				
April	7.4° C	6.6° C	11.1° C	4.4° C
(4/6-4/13 data absent)				
May	10.7° C	9.6° C	16.7° C	6.7° C
June	15.1° C	13.2° C	18.3° C	11.1° C
July	15.0° C	13.1° C	18.3° C	11.1° C
(7/4-7/5 data absent)				
August	17.2° C	15.3° C	19.4° C	12.2° C
September	12.7° C	11.8° C	16.7° C	8.9° C

MONTH	MAXIMUM	MINIMUM	Hi	Lo
1987				
April	9.4° C	8.3° C	12.2° C	6.1° C
May	12.0° C	11.1° C	14.4° C	8.9° C
June	14.6° C	12.9° C	19.4° C	9.4° C
July	15.9° C	14.2° C	18.3° C	12.2° C
August	16.2° C	14.3° C	18.9° C	12.2° C
September	13.7° C	12.6° C	18.9° C	10.0° F
1988				
April	7.3° C	6.6° C	8.9° C	5.6° C
May	7.9° C	7.2° C	10.0° C	5.0° C
June	10.4° C	9.4° C	13.9° C	6.7° C
July	13.3° C	11.5° C	16.7° C	8.3° C
August	13.2° C	11.3° C	15.6° C	9.4° C
September	10.9° C	9.9° C	13.9° C	7.8° C

II. Kalama Hatchery Spring Chinook Salmon Data

Year: 1985

Arrival of spring chinook salmon to hatchery: June 7

Total number of arrivals: males/47, females/49

Total number of adults: 96

Total number of mortalities: males/8, females/4

Total number of fish spawned: males/39, females/45

Total number of eggs: 200,000 Egg mortality: 7,700 (3.85% egg loss)

Year: 1986

Arrival of spring chinook salmon to hatchery: May 15

Total number of arrivals: males/297, females/177

Total number of adults: 474

Total number of mortalities: males/31, females/35

Total number of fish spawned: males/, females/142

Total number of eggs: 584,800 Egg mortality: 52,200 (8.9% egg loss)

Year: 1987

Arrival of spring chinook salmon to hatchery: May 8

Total number of adults: 1,034

Total number of mortalities: males/94, females/130

Total number of eggs: 986,200 (20% egg loss)

Year 1988:

Arrival of spring chinook salmon to hatchery: May 12

Total number of adults: 932

Total number of mortalities: males/ll3, females/159

Total number of eggs: 954,000 (11.4% egg loss)

III. Egg Lot Survival and Mortality through Hatch - University of Washington

Lot	% Survival	% Mortality
I	98.0%	2.0%
2	85.6%	14.4%
3	92.4%	7.6%
4	90.8%	9.2%
5	93.6%	6.4%
6	95.0%	5.0%

Lot	% Survival	% Mortality
7	83.8%	I6.2%
8	46.0%	54.0%
9	93.6%	6.4%
10	93.6%	6.4%
11	**0.0%**	**100%**
12	75.2%	24.8%
13	87.6%	12.4%
14	90.0%	10.0%

IV: Egg Lot Survival to the Eyed Stage - Kalama Falls State Hatchery

Lot	% Survival	Live Eggs	Dead Eggs
1	98.9%	5,828	59
2	95.4%	4,662	224
3	98.8%	4,954	57
4	97.9%	4,517	94
5	95.2%	3,788	188
6	80.3%	4,225	1,032
7	93.0%	6,556	490
8	66.6%	3,351	1,680
9	97.8%	5,828	130
10	98.6%	4,953	70
11	59.7%	2,477	1,671
12	87.5%	1,400	200
13	71.5%	1,960	780
14	37.5%	1,350	2,250

V: Average Incubation Trough Water Temperature, Dissolved Oxygen, and pH

	Average	Hi	Lo	DO	pH
Inlet	9.0° C	9.5° C	8.5° C	7mg/ml	7
Outlet	9.2° C	10.0° C	8.5° C	7mg/ml	7

* On November 2, 1988 DO was determined to be 5 mg/ml oxygen at both the inlet and outlet. Hatching began on November 1, 1988.

Average Temperature Difference Between Inlet and Outlet: 0.24° C (0.24° C greater at the outlet)

VI: Rate of Development of Eggs

A. Incubation to Eyed Stage

<u>Lots 1-11</u>

Egg Take: September 7, 1988

Eyed Stage: October 4, 1988

Days to Eyed: 28

<u>Lots 12-13</u>

Egg Take: September 14, 1988

Eyed Stage: October 11, 1988

Days to Eyed: 28

<u>Lot 14</u>

Egg Take: September 26, 1988

Eyed Stage: October 22, 1988

Days to Eyed: 27

B. Eyed Stage to First Hatch

Lot	Days
1	29
2	29
3	29
4	31
5	34
6	29
7	29
8	31
9	34
10	34
11	34
12	30
13	30.5
14	33.5

C. First Hatch to Complete Hatch

Lot	Days	
	Cup 1	Cup 2
1	2	2
2	10	10
3	12	12
4	24	19
5	16	7
6	7	8

Lot	Days	
	Cup 1	Cup 2
7	4	7
8	17	3
9	8	8
10	11	11
11	100% mortality	
12	9	13
13	19	10
14	10	11

VII: Egg Volume and Weight Measurements

Lot	Volume (10 eggs/20ml distilled water)	Weight(10 eggs)
1	2.7 ml	.5682
2	2.6 ml	.5097
3	2.8 ml	.5832
4	2.6 ml	.5762
5	2.6 ml	.5504
6	2.6 ml	.5602
7	2.5 ml	.5091
8	2.6 ml	.4972
9	2.6 ml	.5023
10	2.6 ml	.5644
11	2.5 ml	.5084
12	2.5 ml	.4363
13	2.4 ml	.3465
14	2.3 ml	.3538

IX: REFERENCES:

ADAMS, T., and K. SULLIVAN. 1987. A preview of a simple stream heating model. Prepared for the TFW Subcommittee on Temperature.

ARMY CORPS OF ENGINEERS. 1986. Annual fish passage report: Columbia and Snake Rivers for salmon, steelhead and shad. North Pacific Division Corps of Engineers, U. S. Army Engineer District Portland and Walla Walla.

BEACHAM, T. D., and C. B. MURRAY. 1986. Effect of female size, egg size, and water temperature on developmental biology of chum salmon *(Oncorhynchus keta)* from the Nitinat River, British Columbia. Can. J. Fish. Aquat. Sci. 42: 1755-1765.

BEACHAM, T. D., and C. B. MURRAY. 1986. Comparative developmental biology of pink salmon *Oncorhynchus gorbuscha*, in Southern British Columbia. J. Fish Biology 28: 233-246.

BERMAN, C. 1988. Current and proposed research trends concerning temperature sensitivity of salmonids, draft report. Fisheries Research Institute and The Center for Streamside Studies, University of Washington.

BILTON, H. T., R. B. MORLEY, A. S. COBURN, and J. VAN TYNE. I984. The influence of time and size at release of juvenile coho salmon *(Oncorhynchus kisutch)* on returns at maturity; results of releases from Quinsam River Hatchery, B. C., in 1980. Can. Tech. Rep. of Fish. and Aquat. Sci. No. 1306.

BILTON, H. T., D. F. ALDERDICE, and J. SCHNUTE. 1980. Increasing adult returns of hatchery-produced coho salmon through optimization of time and size at juvenile release. Proc. No. Aqua. Symp.

BOUCK, G. R., G. A. CHAPMAN, P. W. SCHNEIDER, and D. G. STEVENS. 1975. Effects of holding temperatures on reproductive development in adult sockeye salmon *(Oncorhynchus Nerka)*. pp. 24-40. In: J. R. Donaldson (ed.) 26th Annual Northwest Fish Culture Conference, Otter Creek, Oregon.

BRANNON, E. L. 1987. Mechanisms stabilizing salmonid fry emergence timing. Can. Spec. Publ. Fish. Aquat. Sci. 96.

CENTER FOR STREAMSIDE STUDIES IN FORESTRY, FISHERIES, AND WILDLIFE (CSS) Research Plan. 1988.

COMBS, B. D. 1965. Effect of temperature on the development of salmon eggs. Prog. Fish-Cult. 27: 134-137.

CUNJAK, R. A. 1988. Physiological consequences of overwintering in streams: the cost of acctimitization? J. Fish. Aquat. Sci. 45: 443-452.

CUNJAK, R. A., and G. POWER. 1987. The feeding and energetics of stream-resident trout in winter. J. Fish Biol. 31: 493-511.

DONG, J. N. 1981. Thermal tolerance and rate of development of coho salmon embryos. Master's thesis. University of Washington.

FLEMING, I. A., and S. NG. 1987. Evaluation of techniques for fixing, preserving, and measuring salmon eggs. Can. J. Fish. Aquat. Sci. 44: 1957-1962.

GARLING, D. L., and M. MASTERSON. 1985. Survival of Lake Michigan chinook salmon eggs and fry incubated at three temperatures. Prog. Fish-Cult. 47: 63-.66.

HARTMAN, G. (Ed.). 1982. Proceedings of the Carnation Creek study, a 10 year review. Malaspina College, Nanaimo, British Columbia.

HEMING, T. A. 1982. Effects of temperature on utilization of yolk by chinook salmon *(Oncorhynchus tshawytscha)* eggs and alevins. Can. J. Fish. Aquat. Sci. 39: 184-190.

HOLTBY, L. B. 1988. Effects of logging on stream temperatures in Carnation Creek, British Columbia, and associated impacts on the coho salmon *(Oncorhynchus kisutch)*. Can. J. Fish. Aquat. Sci. 45: 502-515.

KAMLER, E., and T. KATO. 1983. Efficiency of yolk utilization by *Salmo gairdneri* in relation to incubation temperature and egg size. Pol. Arch. of Hydrobiol. 30: 2714306.

LINLEY, T. J. 1988. Maternal influences upon embryonic development in chinook salmon *(Oncorhynchus tshawytscha)*. Master's thesis. University of Washington.

MORING, and LANTZ. 1975. Alsea watershed study: part I, biologicai studies. Fish. Res. Rep. No. 9, Oregon Department of Fish and Wildlife.

MURRAY, C. B., and J. D. MCPHAIL. 1988. Effect of temperature on the development of five species of Pacific salmon *(Oncorhynchus)* embryos and alevins. Can. J. Zool. 66: 266-273.

N-EITZEL, D. A., and C. D. BECKER. 1985. Tolerance of eggs, embryos, and alevins of chinook salmon to temperature changes and reduced humidity in dewatered redds. Trans. Am. Fish. Soc. I14: 267 -273.

OLSON, P. A., and R.. E. NAKATANI. 1969. Effects of chronic variable water temperatures on survival and growth of young chinook salmon, pp. 17-20. In: Biological effects of thermal discharges: annual progress report for 1968. AEC Research and Development Report. Battelle Memorial Institute Pacific Northwest Laboratories. Richland, Washington. BNWL-1050.

OLSON, P. A., and R. F'. FOSTER. 1955. Temperature tolerance of eggs and young of Columbia River chinook salmon. Trans. Am. Fish. Soc. 85: 203-207.

RINGLER, N. H., and J. D. HALL. 1975. Effects of logging on water temperature and dissolved oxygen in spawning beds. Trans. Am. Fish. Soc. 104: 111-121.

SMITH, C. E., and W. P. DWYER, and R. G. PIPER. 1983. Effect of water temperature on egg quality of cutthroat trout. Prog. Fish-Cult. 43: 176-1.78.

STRANGE, R. J. 1980. Acclimation temperature influences cortisol and glucose concentrations in stressed channel catfish. Trans. Am. Fish. Soc. 109: 298-303.

TANG, J., M. D. BRYANT, and E. L. BRANNON. 1987. Effect of temperature extremes on the mortality and development rares of coho salmon embryos and alevins. Prog. Fish-Cult. 49: 167-I74.

THOMAS, R. E., I. A. GHARRET, M. G. CARLS, S. D. RICE, A. MOLES, and S. KORN. 1986. Effects of fluctuating temperature on mortality, stress, and energy reserves of juvenile coho salmon. Trans. Am. Fish. Soc. 115: 52-59.

TIPPING, J. 1986. Effect of release size on return rates of hatchery 'sea-run cutthroat trout. Prog. Fish-Cult. 48: 195-197.

WAHLE, R. J., and R. E. PEARSON. 1987. A listing of Pacific Coast spawning streams and hatcheries producing chinook and coho salmon with estimates on numbers of spawners and data on hatchery releases. NOAA Technical Memorandum NMFS F/NWC-122. U. S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

WAHLE, R. J., and R. Z. SMITH. 1979. A historical and descriptive account of Pacific Coast anadromous salmonid rearing facilities and a summary of their release by region, 1960-76. NOAA Technical Report, NMFS SSRF-736. U. S. Department of Commerce, National Oceanic and Atmospheric Administration, and National Marine Fisheries Service.